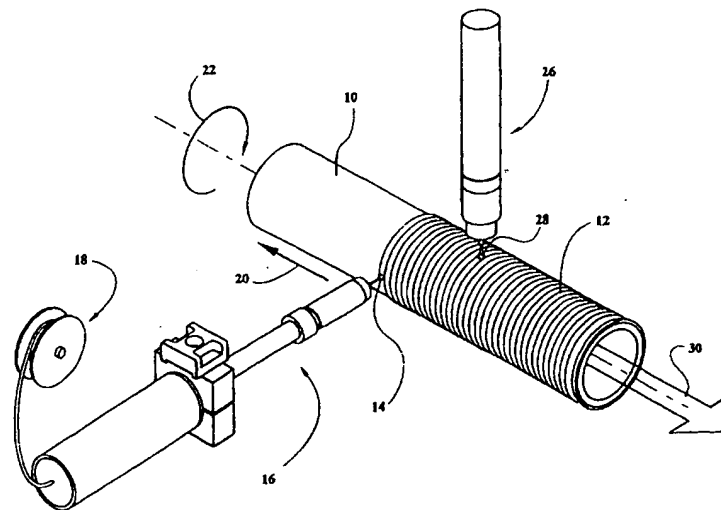




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification <sup>6</sup> : <b>B23K 9/04</b>	<b>A1</b>	(11) International Publication Number: <b>WO 98/05463</b> (43) International Publication Date: 12 February 1998 (12.02.98)
(21) International Application Number: PCT/US97/13661 (22) International Filing Date: 1 August 1997 (01.08.97) (30) Priority Data: 08/692,333                      5 August 1996 (05.08.96)                      US (71) Applicant: WELDING SERVICES, INC. [US/US]; 2225 Skyland Court, Norcross, GA 30071 (US). (72) Inventor: HULSIZER, Philip, N.; 1167 Bymwyck Road, Atlanta, GA 30319 (US). (74) Agents: ROBERTS, Larry, A. et al.; Jones & Askew, LLP, 37th floor, 191 Peachtree Street, N.E., Atlanta, GA 30303 (US).	(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZW, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  Published With international search report.	

(54) Title: DUAL PASS WELD OVERLAY METHOD AND APPARATUS



## (57) Abstract

A bead (12) of overlay material is applied onto a tube (10) by melting the overlay material. When a portion of the bead (12) has solidified, that portion is reheated using a second welding process. The tube (10) is rotated with respect to the weld heads (16, 26), while the weld heads (16, 26) move along the longitudinal axis of the tube (10). The first weld head (16) employs a gas-metal arc welding process, and the second weld head (26) employs a gas-tungsten arc welding process. The apparatus for the method includes a frame supporting the tube (10) for rotation about its longitudinal axis. A movable support adjustably supports the weld heads (16, 26) and moves the heads (16, 26) along the longitudinal axis of the tube. A weld overlay material feeder (18) is operatively associated with the first head (16).

**FOR THE PURPOSES OF INFORMATION ONLY**

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AL	Albania	ES	Spain	LS	Lesotho	SI	Slovenia
AM	Armenia	FI	Finland	LT	Lithuania	SK	Slovakia
AT	Austria	FR	France	LU	Luxembourg	SN	Senegal
AU	Australia	GA	Gabon	LV	Latvia	SZ	Swaziland
AZ	Azerbaijan	GB	United Kingdom	MC	Monaco	TD	Chad
BA	Bosnia and Herzegovina	GE	Georgia	MD	Republic of Moldova	TG	Togo
BB	Barbados	GH	Ghana	MG	Madagascar	TJ	Tajikistan
BE	Belgium	GN	Guinea	MK	The former Yugoslav Republic of Macedonia	TM	Turkmenistan
BF	Burkina Faso	GR	Greece			TR	Turkey
BG	Bulgaria	HU	Hungary	ML	Mali	TT	Trinidad and Tobago
BJ	Benin	IE	Ireland	MN	Mongolia	UA	Ukraine
BR	Brazil	IL	Israel	MR	Mauritania	UG	Uganda
BY	Belarus	IS	Iceland	MW	Malawi	US	United States of America
CA	Canada	IT	Italy	MX	Mexico	UZ	Uzbekistan
CF	Central African Republic	JP	Japan	NE	Niger	VN	Viet Nam
CG	Congo	KE	Kenya	NL	Netherlands	YU	Yugoslavia
CH	Switzerland	KG	Kyrgyzstan	NO	Norway	ZW	Zimbabwe
CI	Côte d'Ivoire	KP	Democratic People's Republic of Korea	NZ	New Zealand		
CM	Cameroon			PL	Poland		
CN	China	KR	Republic of Korea	PT	Portugal		
CU	Cuba	KZ	Kazakhstan	RO	Romania		
CZ	Czech Republic	LC	Saint Lucia	RU	Russian Federation		
DE	Germany	LI	Liechtenstein	SD	Sudan		
DK	Denmark	LK	Sri Lanka	SE	Sweden		
EE	Estonia	LR	Liberia	SG	Singapore		

5

1

10

## **“DUAL PASS WELD OVERLAY METHOD AND APPARATUS”**

15

### **Technical Field**

20

The present invention relates to a method and apparatus for overlaying metal tubing. More specifically, the invention relates to a method and apparatus which employs two separate welding processes in a single pass to overlay conventional tube stock.

### **Background of the Invention**

25

When selecting metal tubing for a particular application, the demands of the application may require physical characteristics which cannot be met by a single composition. Some alloys, for example, may provide suitable characteristics in terms of mechanical properties but lack the necessary resistance to corrosion, abrasion, or both. Other alloys may provide suitable performance in resisting corrosion and abrasion but lack the requisite structural characteristics.

30

35

In such an instance, the solution is normally found in overlaying a tubing having the requisite structural characteristics with an alloy having the desired resistance to corrosion and abrasion. Such composite tubing is typically manufactured in either of two ways: by co-extruding the two

compositions during the manufacturing process or by applying a weld overlay to a pre-existing metal tube. The present invention is concerned with the latter approach.

5 An optimal weld overlay has several characteristics. First, the weld penetration of the tube stock is carefully controlled to ensure the optimum fusion between the weld overlay and the tube stock. Second, the exterior surface of the weld overlay will be smooth. Third, the thickness of the weld overlay and the resulting dimensions of the overlaid tube can be closely controlled. Unfortunately, using  
10 conventional weld overlay techniques, these characteristics tend to be mutually exclusive, and the weld overlay is at best a compromise. If the voltage and current of the weld head are controlled to provide the smoothest possible exterior surface, then penetration of the tube stock tends to be excessive and  
15 uneven. Stresses resulting from bending of the tube or from thermal cycling can cause the weld overlay to separate from the underlying tube stock. On the other hand, if the voltage and current of the weld head are controlled to optimize penetration, then the exterior surface of the weld overlay tends to be rough and uneven. A rough, uneven exterior surface of a weld overlay suffers numerous disadvantages. It can make the tube more difficult to bend, which can result in an uneven distribution of stresses during bending and thermal cycling. It  
20 can also affect the thickness of the weld overlay and the resulting dimensions of the overlaid tube. When the tubes are used to fabricate a tube panel, adjacent tubes with uneven surfaces can create undesirable gaps between the tubes.

25 Thus, there is a need for a weld overlay process and article of manufacture which provides optimum penetration of the underlying tube stock and a smooth, even exterior surface.

30 There is a further need for a weld overlay process and article of manufacture which can provide optimum penetration of the underlying tube stock and a smooth, even  
35

exterior surface and also control over the thickness of the overlay and the resulting dimensions of the overlaid tube.

There is still a further need for a weld overlay process and article of manufacture which can provide optimum penetration of the underlying tube stock and a smooth, even exterior surface and also provide uniform residual stresses within the overlaid tube.

### Summary of the Invention

Stated generally, the present invention comprises a process for applying a weld overlay to a tube. Using a first welding process, a bead of overlay material is applied onto a tube by melting and transferring the overlay material. In a disclosed embodiment this heating is accomplished by a metal-inert gas welding process, more specifically a pulse spray transfer. When a portion of the bead solidifies, that portion is re-heated using a second welding process. In a disclosed embodiment this re-heating is accomplished by a tungsten-inert gas welding process. In the disclosed embodiment, the tube is rotated with respect to the weld heads, while the weld heads move along the longitudinal axis of the tube. According to the disclosed embodiment, the first weld head employs a gas-metal arc welding process, and the second weld head employs a gas-tungsten arc welding process.

In a second aspect the present invention comprises an apparatus for applying a weld overlay to a metal tube. A frame supports tube for rotation about its longitudinal axis. A movable support adjustably supports first and second weld heads and is configured to move the weld heads along the longitudinal axis of the tube. The weld heads are adjustably supported on the movable support in predetermined relation to the tube. A weld overlay material feeder is operatively associated with the first weld head and, in conjunction with the first weld head, applies a weld overlay to an exterior surface of the tube.

Thus it is an object of the present invention to provide an improved method and apparatus for applying a weld overlay onto a tube.

5 It is another object of the present invention to provide an improved method and apparatus for applying a weld overlay onto a tube wherein the procedure both optimizes the penetration of the tube material and provides a smooth, even exterior surface.

10 Still another object of the present invention is to provide an improved method and apparatus for applying a weld overlay onto a tube wherein the procedure both optimizes the penetration of the tube material and provides a smooth, even exterior surface while also providing control over the thickness of the overlay and the resulting dimensions of the overlaid tube.

15 It is yet another object of the present invention to provide a weld overlay process and article of manufacture which can provide optimum penetration of the underlying tube stock and a smooth, even exterior surface and also provide uniform residual stresses within the overlaid tube.

20 Other objects, features, and advantages of the present invention will become apparent upon reading the following specification, when taken in conjunction with the drawings and the appended claims.

25

### **Brief Description of the Drawings**

**FIG. 1** is a schematic diagram illustrating a method of applying a weld metal overlay onto a metal tube, according to the present invention.

30

**FIG. 2** is a perspective view of an apparatus for performing the method of **FIG. 1**.

**FIG. 3A** is an elevation view of a tube support of the apparatus of **FIG. 2** with the support shown in its normal, closed position; **FIG. 3B** is an elevation view of the tube

support of FIG. 3A showing the support in its open position for accepting a metal tube therewithin.

### Detailed Description of the Disclosed Embodiment

5 Referring now in more detail to the drawings, in which like numerals indicate like elements throughout the several views, FIG. 1 illustrates a method of applying to a metal tube stock 10 a weld metal overlay 12. Typical examples of suitable material for the tube stock 10 would include carbon or low alloy steel. Examples of suitable weld overlay material include alloy 309 and alloy 625. However, it will be appreciated that the method and apparatus disclosed hereinbelow are equally suitable for other tube stock materials and other weld overlay materials depending upon the characteristics desired of the finished product and subject to the limitations of compatibility to the tube stock material and the weld overlay material.

15 The weld overlay is applied at a first location 14 by a gas metal arc welding ("GMAW") torch or weld head, also known as a metal inert gas ("MIG") torch. A wire feeder 18 is associated with the MIG torch 16 to feed a metal overlay material to the weld location 14. In the disclosed embodiment, the MIG torch 16 is of conventional design and is the model A2521-3072T4 manufactured by Bernard. The associated wire feed 18 is also of conventional design and, in the disclosed embodiment, is the model 554D, manufactured by Miller.

25 The MIG torch 16 in the disclosed embodiment is longitudinally advanced past the weld head in the direction indicated by the arrow 20, while the tube stock 10 is simultaneously rotated past the torch in the direction indicated by the arrow 22. When viewed from the right end of the tube stock 10 as shown in FIG. 1, such that the tube stock rotates in a clockwise direction, the MIG torch 16 applies the weld overlay at a location corresponding to approximately the nine

o'clock position on the outer circumference of the tube stock. This location is advantageous because applying the weld metal overlay material to the tube stock in a vertical position minimizes dilution of the base metal and weld wire. The MIG weld head 16 oscillates in a direction parallel to the longitudinal axis of the tube stock 10 (in the same direction previously indicated by the arrow 20) to work the weld bead further.

A gas tungsten arc welding ("GTAW") torch, also known as a tungsten inert gas ("TIG") torch or weld head 26, is disposed to treat the weld metal overlay 12 at a point which is spaced apart from the MIG torch 16 along the longitudinal axis of the tube stock 10. In the disclosed embodiment, the TIG torch 26 is of conventional design and is the model WP17 manufactured by Weld Craft. Again as viewed from the right end of the tube stock 10 as shown in FIG. 1, with the tube stock rotating in a clockwise direction, the TIG torch 26 heats the weld metal overlay 12 at a location substantially corresponding to the twelve o'clock position on the circumference of the tube stock 10. No wire feed is associated with the TIG torch 26, and no additional weld metal overlay material is applied to the circumference of the tube stock 10 at the location 28 which is heated by the TIG weld head 26.

The current and voltage of the MIG weld head 16 are controlled to optimize fusion between the weld overlay 12 and the tube stock 10. The resulting weld overlay will tend to have a rough, uneven surface. The current and voltage of the TIG weld head 26 are then controlled to melt or to "wash" and to re-shape the outer portion of the weld bead. The re-heating process achieved by the TIG weld head 26 advantageously does not re-melt the entire weld bead. Instead, the weld bead is heated to a temperature sufficient to melt only a portion of the weld bead but not sufficient to increase dilution of the weld metal or to increase penetration into the base metal.



The use of two separate weld heads 16, 26 with weld metal overlay material being applied only in conjunction with the first weld head 16 provides the following advantages. The voltage, amperage, and wire feed rate of the MIG weld head 16 can be controlled to optimize penetration of the weld bead without regard to the effect on the outer circumference of the bead. In contrast, the voltage and amperage of the TIG weld head can be controlled to provide fine contouring to the circumference of the weld overlay material 12. In addition, the second heating process accomplished by the TIG weld head 26 provides for uniform residual stresses in the weld bead and lowers the hardness of the heat-affected zone by as much as 8-10 points on the Rockwell "C" scale.

To control the temperature of the tube stock and to control the rate of cooling of the weld overlay metal, water is flowed through the tube stock during the welding process, as indicated generally by the arrow 30. The volume and flow rate of the water are sufficient to maintain this tube stock at an interior temperature of 80-100°F.

#### *Example*

309 alloy weld overlay material is applied onto carbon or low alloy steel tube stock. The current of the MIG torch 16 is set at 185-220 amps, and the voltage is set at 23-27 volts. The wire feed speed is 360-600 inches per minute, preferably 400-480 inches per minute. The tube stock is rotated at 18-40 inches per minute, preferably 20-36 inches per minute. For tube stock having a three inch diameter, the tube stock rotates from 2-4 revolutions per minute. The MIG weld head 16 applies the weld overlay material at a density of three to six beads per inch, preferably about four beads per inch. The TIG torch 26 is longitudinally spaced apart from the MIG torch by a distance of approximately five inches. The MIG process heats the weld metal to a temperature of approximately 2,400-2,500°F. By the time a particular location along the continuous weld bead has reached the TIG

torch 26, the weld bead has solidified. The TIG torch 26 reheats the outer portion of the previously applied bead above a temperature of approximately 1,500-1,600°F to re-melt a portion of the bead. According to this method, the depth of penetration can be controlled within tolerances of approximately  $\pm .003$  inches, and the outer diameter contour and dimension can be controlled within tolerances of approximately  $\pm .007$  inches.

FIG. 2 illustrates an apparatus 100 for carrying out the method illustrated in FIG. 1. The apparatus 100 includes an elongated frame 102 having side walls 104 and 106. One end of the tube stock 10 is gripped in a chuck 110 which is rotationally driven by an electric motor or other suitable means 111. Rotary unions 112 cap each end of the tube stock 10, and hoses 114 coupled to the rotary unions 112 introduce a coolant such as water into one end of the tube stock 10 and withdraw it from the other. A rotary ground 116 grounds the tube stock 10.

The frame 102 further comprises upper rails 120 disposed along the upper edge of each of the side walls 104, 106. A wheeled platform 122 rolls along the rails 120. Gears (not shown) operatively associated with the platform 122 and driven by an electric motor or other suitable means engage a gear rack 124 formed along the lower surface of each of the upper rails 120 to move the platform 122 along the length of the frame 102.

The platform 122 includes a control panel 128 by which the voltage, current, and speed of oscillation of the two weld heads 16, 26, the wire feed speed of the wire feeder 18, and the speed of movement of the platform 122 are set.

When mounted to the frame 102 as thus described, the tube stock 10 extends over the platform 122. The MIG weld head 16, wire feed 18, and TIG weld head 26 are adjustably mounted to the platform 122 by a suitable

mounting means 130 so that they can be properly oriented with respect to the tube stock 10. Affixed to the mounting means 130 is a guide 132 in the form of a short length of aluminum structural angle disposed in an inverted "V" position. The guide 132 rides on top of the tube stock 10 to maintain the proper relationship between the tube stock and the mounting means 130. The platform 122 moves along the frame 102 to effect relative longitudinal movement between the weld heads 16, 26 and the tube stock 10. Simultaneously the tube stock 10 rotates to effect relative rotational movement between the tube stock and the weld heads 16, 26. The speed at which the platform 122 moves along the rails 120 of the frame 102 is controlled with respect to the speed at which the tube 10 is rotated so that the weld heads 16, 26 have advanced by a distance corresponding to the width of the weld bead 12 for each rotation of the tube.

To support the weight of the tube stock 10 along its length, a plurality of supports 140 are provided. As can be seen in FIG. 3, each support 140 includes an upright stanchion 142. A frame 144 is mounted to the stanchion 142 for movement toward and away from the stanchion in the direction indicated by the arrow 145. In the disclosed embodiment, movement of the frame 144 toward and away from the stanchion 142 is affected by a pair of threaded rods 146, 147, though other suitable mechanisms may be used. The support further includes upper and lower wheels 148, 149 rotatably mounted to the stanchion 142 and upper and lower wheels 150, 151 rotatably mounted to the frame 144.

As can be seen in FIG. 3B, the upper threaded rod 146 is disengageable from the frame 144 and pivotably opens as indicated by the arrow 154 to permit the support 140 to be positioned around the tube stock 10. The frame 144 is then closed by turning the threaded rods 146, 147 to bring the upper and lower wheels 148-151 into contact with the outer circumference of the tube stock 10. The spacing between the

frame 144 and the stanchion 142 is adjusted to bring all four wheels 148-151 into contact with the circumference of the tube stock. As the tube stock 10 is rotatably driven, the wheels 148-151 rotate freely to permit the tube stock to rotate within the support 140.

At the start of the weld overlay process, the platform 122 is located at the far right end of the frame 102 as seen in FIG. 2. The three supports 140 are spaced along the length of the tube stock 10 to the left of the platform, as seen in FIG. 2, to support the weight of the tube stock.

As the platform 122 moves along the frame 102 toward the left, the rightmost support 140 is removed and repositioned to the right of the platform. As the platform 122 moves further toward the left, the next support 140 is moved out of the way and repositioned to the right of the platform. Similarly, as the platform 122 continues to move, the last support 140 is repositioned to a location on the right side of the platform as seen in FIG. 2.

There may be occasions when it would be desirable to apply a second weld metal overlay on top of the first weld metal overlay 12. As an example, whenever a weld overlay is applied directly onto the exterior surface of a tube, some dilution of the weld metal occurs. Application of a second weld overlay provides an outer layer which is virtually pure weld metal. When applying two weld overlays, it may be desirable to use a less-expensive metal such as alloy 304 for the bottom layer and a weld metal having more of the desired chemistry and physical properties for the top layer, such as alloy 309. In such a case, the TIG weld head 26 would be moved further away from the MIG weld head 16, and a second MIG weld head with associated wire feed would be positioned between the first MIG weld head 16 and the TIG weld head 26. A first weld metal overlay 12 would be applied onto the tube stock 10 as previously described. At a point sufficiently spaced apart from the first MIG weld head 16 that the first

weld metal overlay 12 has solidified, a second weld metal overlay is applied by the second MIG weld head and associated wire feed. Advantageously the second MIG weld head is also positioned at approximately the 9 o'clock position with respect to the tube stock 10. At a point sufficiently spaced apart from the second MIG weld head that the second weld metal overlay has solidified, the TIG weld head 26 heats the second weld metal overlay to provide a smooth, contoured outer surface.

In the disclosed embodiment the MIG weld head 16 and the TIG weld head 26 are spaced apart by five inches along the longitudinal axis of the tube stock 10. The longitudinal spacing of five inches between the MIG and TIG weld heads 16, 26 in the disclosed embodiment is selected because it is not physically possible to position the particular weld heads of the disclosed embodiment any closer together. However, it will be appreciated that, depending upon various factors, a portion of the weld bead 12 may have solidified before the platform 122 has moved five inches. Thus in the case of weld heads having different configurations, it is possible that the two weld heads can be positioned closer together than five inches and still achieve the desired result.

While the embodiment disclosed above employs a platform 122 which moves along the frame 102 to effect relative longitudinal movement between the weld heads 16, 26 and the tube stock 10, it will be appreciated that relative longitudinal movement between the weld heads and the tube stock can also be achieved by holding the weld heads steady and moving the tube longitudinally with respect to the weld heads. Thus a means for effecting relative longitudinal movement between the weld heads and the tube could comprise either means for moving the weld heads while the tube remains longitudinally fixed, or means for moving the tube longitudinally with the weld heads remaining fixed.

Finally, it will be understood that the preferred embodiment has been disclosed by way of example, and that

other modifications may occur to those skilled in the art without departing from the scope and spirit of the appended claims.

## CLAIMS

What is claimed is:

- 5           1.    A process for applying a weld overlay to a tube, comprising the steps of:  
                    using a first welding process, applying a bead of overlay material onto said tube by melting said overlay material;  
10                      permitting a portion of said bead to solidify; and  
                    using a second welding process, re-heating said portion of said bead which has solidified to re-melt the outer portion of said solidified portion of said bead.  
15
2.    The process of Claim 1, wherein said process is a continuous process such that said bead of overlay material is being applied onto said tube at a first location simultaneously with a solidified portion of said bead being re-heated at a second location.  
20
3.    The process of Claim 1, wherein said first welding process comprises a gas metal arc welding process.
- 25           4.    The process of Claim 1, wherein said second welding process is performed without adding any additional overlay material onto said tube.
- 30           5.    The process of Claim 1, wherein said second welding process comprises a gas tungsten arc welding process.

6. The process of Claim 1, wherein said step of applying a bead of overlay material onto a tube comprises the steps of:

holding a first weld head in a substantially fixed position with respect to said tube;

rotating said tube about a longitudinal axis to bring successive portions of the outer circumference of said tube beneath said first weld head such that said bead of overlay material is applied onto said successive portions of said outer circumference of said tube; and

effecting relative longitudinal movement between said first weld head and said tube to apply said bead along the length of said tube.

7. The process of Claim 6, wherein said bead of overlay material is applied to said tube at a location on said tube which is at approximately the vertical midpoint of said tube and on a side of said tube which is rotating upward beneath said weld head.

8. The process of Claim 6, wherein said step of re-heating said portion of said bead which has solidified comprises the step of holding a second weld head in a substantially fixed position with respect to said tube such that said step of rotating said tube about said longitudinal axis of said tube brings successive portions of the outer circumference of said tube beneath said second weld head.

9. The process of Claim 1, wherein said step of applying said bead of overlay material onto said tube comprises the step of controlling said first welding process to optimize fusion of said weld overlay to said tube without regard to the surface characteristics of the exterior surface of said weld overlay, and



wherein said step of re-heating said portion of said bead which has solidified comprises the step of controlling said second welding process to melt the outer portion of said bead without increasing dilution of the overlay material or increasing dilution of the base metal of the tube.

10. An apparatus for applying a weld overlay to a metal tube, comprising:

- a frame for mounting a tube for rotation about a longitudinal axis of said tube;
- a first weld head;
- a second weld head;
- a support mounted to said frame for adjustably supporting said first and second weld heads in such a manner as to be capable of being arranged in predetermined relation to a tube mounted to said frame, said second weld head being spaced from said first weld head along a longitudinal axis of a tube mounted to said frame;
- means for effecting relative longitudinal movement between said support and said tube; and
- a weld overlay material feeder operatively associated with said first weld head for supplying a weld overlay material, said weld overlay feeder being operative in conjunction with said first weld head to apply a weld overlay to an exterior surface of said tube by melting said overlay material and transferring it onto said tube;

whereby said tube is rotatable with respect to said first and second weld heads, and said first and second weld heads are longitudinally movable with respect to said tube.

11. The apparatus of Claim 10, wherein said support is movably mounted to said frame, and wherein said means for effecting relative longitudinal movement between said support and said tube comprises means for moving said support on said frame longitudinally with respect to said tube.

12. The apparatus of Claim 10, wherein said  
second weld head being spaced from said first weld head along  
said longitudinal axis of said tube comprises said second weld  
head being spaced a sufficient distance along said longitudinal  
axis of said tube that a portion of a weld overlay which passes  
beneath said second weld head has solidified.

13. The apparatus of Claim 12, wherein said  
second weld head being spaced a sufficient distance along said  
longitudinal axis of said tube that a portion of a weld overlay  
which passes beneath said second weld head has solidified  
comprises said second weld head being spaced a sufficient  
distance along said longitudinal axis of said tube that a portion  
of a weld overlay which passes beneath said second weld head  
has solidified but remains heated to a temperature higher than  
the ambient temperature.

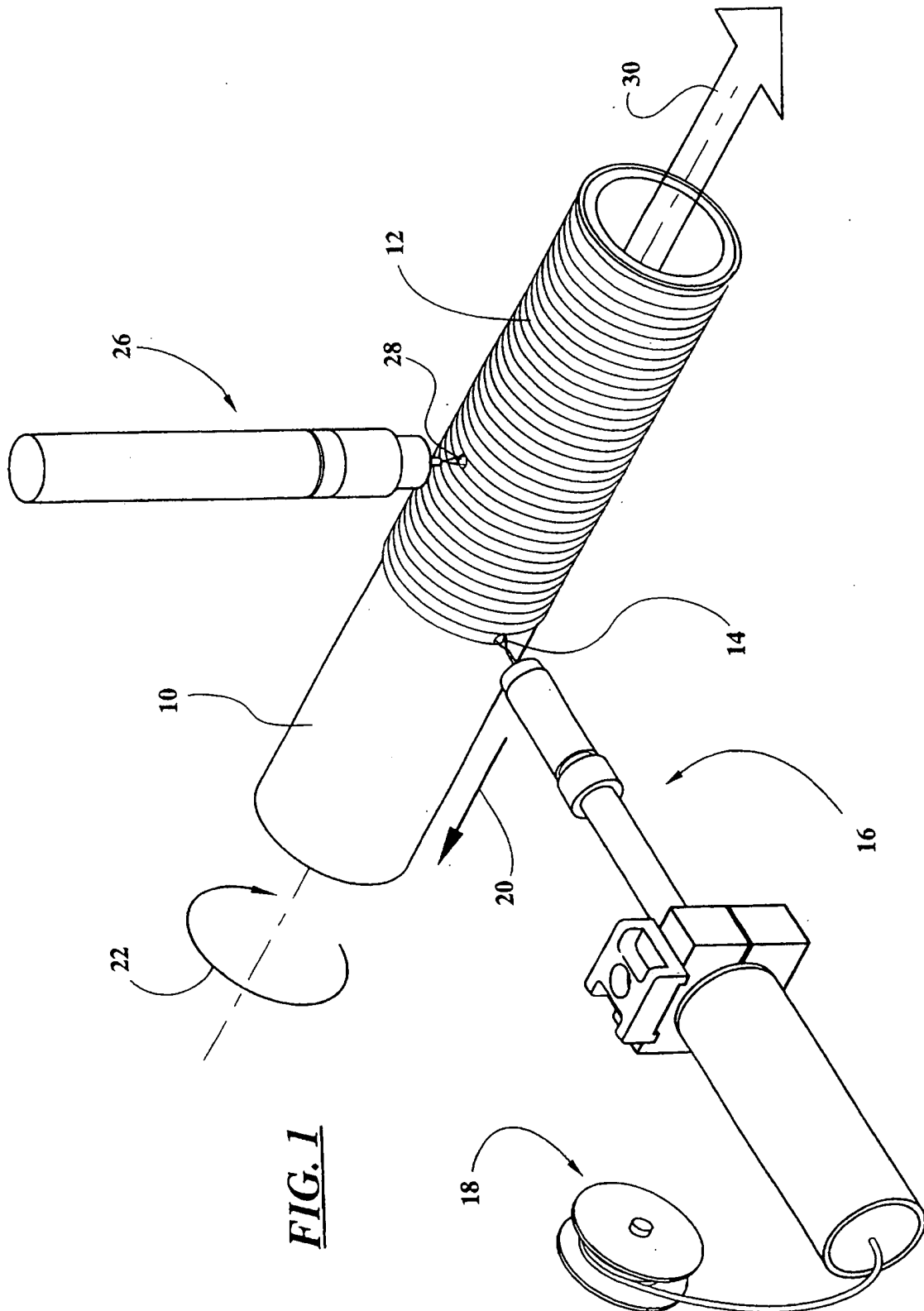
14. The apparatus of Claim 10, further  
comprising means for oscillating said first and second weld  
heads with respect to said tube.

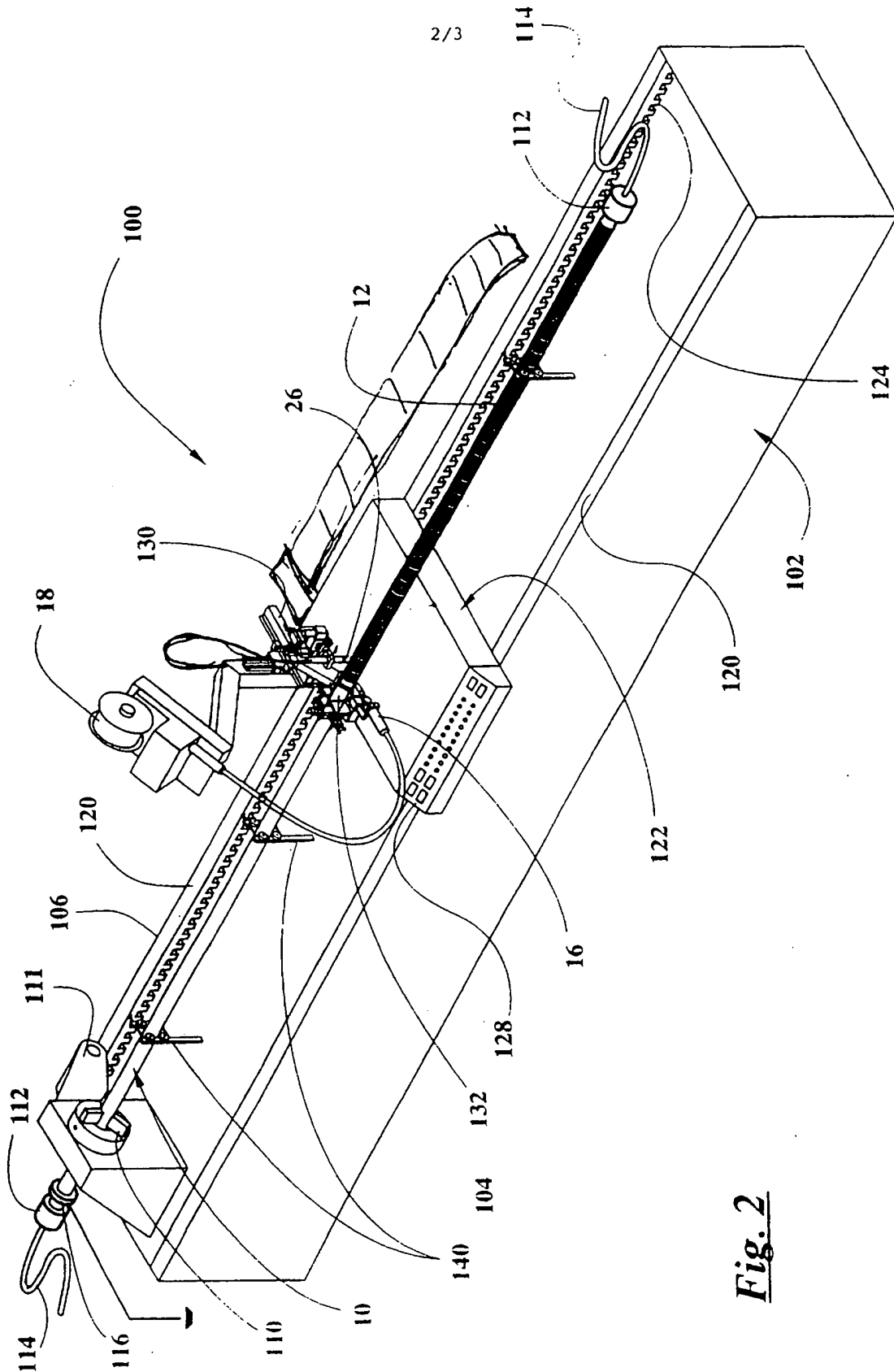
15. The apparatus of Claim 10, wherein said  
first weld head is arranged with respect to said tube so as to  
apply a weld overlay to a location on said exterior surface of  
said tube which is approximately 90° offset from the top of  
said tube.

16. The apparatus of Claim 10, wherein said  
second weld head is arranged with respect to said tube so as to  
heat said weld overlay at a location on said exterior surface of  
said tube which is at approximately the top of said tube.

17. The apparatus of Claim 10, wherein said first weld head comprises a gas-metal arc weld head, and wherein said second weld head comprises a gas-tungsten arc weld head.

1/3





**Fig. 2**

3/3

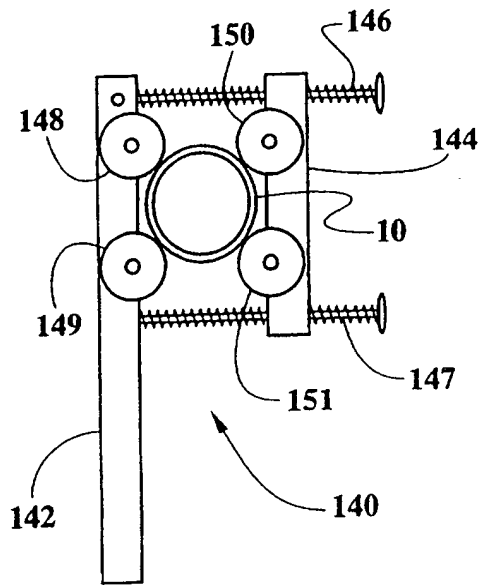


Fig. 3A

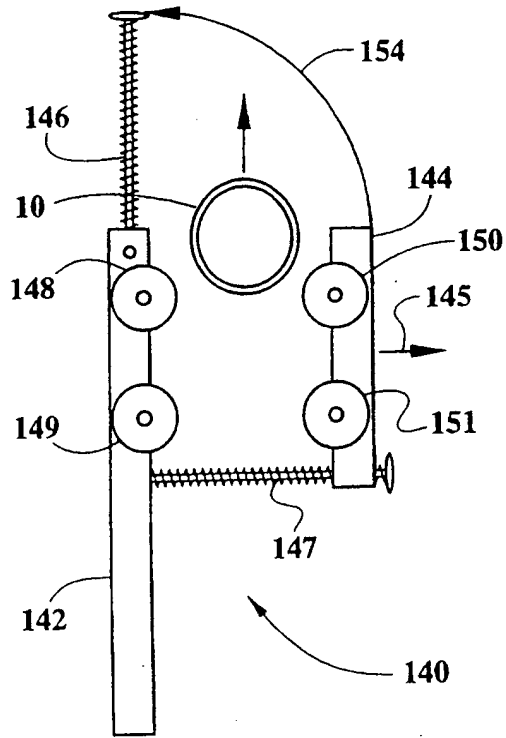


Fig. 3B

## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US97/13661

<b>A. CLASSIFICATION OF SUBJECT MATTER</b> IPC(6) :B23K 9/04 US CL :219/76.14, 125.11 According to International Patent Classification (IPC) or to both national classification and IPC														
<b>B. FIELDS SEARCHED</b> Minimum documentation searched (classification system followed by classification symbols) U.S. : 219/61, 75, 76.12, 76.14, 76.15, 125.11, 125.12, 137R Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)														
<b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>														
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.												
Y	US 2,813,190 A (FELMLEY, JR.) 12 November 1957 (12/11/57), see the entire document.	14												
Y	US 2,756,311 A (PERSSON ET AL.) 24 July 1956 (24/07/56), see figure 1, column 1, and column 4.	1-17												
Y	US 4,948,936 A (LANDRY) 14 August 1990 (14/08/90), see the entire document.	1-17												
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.														
<table border="0"><tr><td>* Special categories of cited documents:</td><td>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</td></tr><tr><td>"A" document defining the general state of the art which is not considered to be of particular relevance</td><td>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</td></tr><tr><td>"E" earlier document published on or after the international filing date</td><td>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</td></tr><tr><td>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</td><td>"&amp;" document member of the same patent family</td></tr><tr><td>"O" document referring to an oral disclosure, use, exhibition or other means</td><td></td></tr><tr><td>"P" document published prior to the international filing date but later than the priority date claimed</td><td></td></tr></table>			* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention	"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone	"E" earlier document published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art	"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family	"O" document referring to an oral disclosure, use, exhibition or other means		"P" document published prior to the international filing date but later than the priority date claimed	
* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention													
"A" document defining the general state of the art which is not considered to be of particular relevance	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone													
"E" earlier document published on or after the international filing date	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art													
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"&" document member of the same patent family													
"O" document referring to an oral disclosure, use, exhibition or other means														
"P" document published prior to the international filing date but later than the priority date claimed														
Date of the actual completion of the international search 24 SEPTEMBER 1997		Date of mailing of the international search report 10 OCT 1997												
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230		Authorized officer <i>Bomb for</i> CLIFFORD C. SHAW Telephone No. (703) 308-1712												

Form PCT/ISA/210 (second sheet)(July 1992)\*